PoS PROCEEDINGS OF SCIENCE

A highly collimated jet from the low mass proto-star NGC1333 IRAS 4B

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We imaged the protostars of the nearby region NGC1333 IRAS 4 in the water maser line at 22.2 GHz by using the VLBA in phase referencing at milliarcsecond scale over four epochs spaced by one month to measure proper motions. We measure the absolute positions and proper motions of the H_2O spots to investigate the kinematics of the region from where the jet is launched.

Two protostars (A2 and B) have been detected in a highly variable H_2O maser emission, with an active phase shorter than four weeks. A 70 AU chain of several maser spots, very well aligned, has been observed close to the B protostar. The apparent proper motions have been derived, finding that the H_2O spots are moving along the N-NW direction with projected velocities between 10 and 50 km s^{-1}. We conclude that in IRAS 4B, water maser trace a highly collimated bipolar jet clearly associated with the protostar.

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1. Introduction

NGC1333 is a well-known star forming region containing a large number of proto-stars and located at a distance of 235 pc, according to the recent observations [4] performed with VERA (VLBI Exploration of Radio Astrometry). The IRAS 4 region contains three star forming sites, called 4A, 4B, and 4C, which can be identified in the mm-continuum. High angular resolution cm- and mm-observations [8] have revealed that IRAS 4B is also associated with a bipolar outflow located along the North-South direction [5]. Water (H_2O) masers at 22 GHz in combination with the high angular resolution given by Very Long Baseline Interferometry (VLBI) techniques, represent a unique tool to investigate the mechanism of jet formation and collimation in the earliest star forming phases. All these characteristics make of IRAS4 an excellent laboratory where to study multiple star formation.

2. Observations and Results

Using the VLBA network, we observed H_2O maser emission at 22.2 GHz in phase referencing over four epochs spaced by about four weeks during 2003 (Apr 1st, May 14th, June 11th, July 07th). The duration of each observations was 10 hours in total.

As the four proto-stars (IRAS 4A1, 4A2, 4B, and 4C) fell inside the primary beam of the antennas, during the observation we tracked their barycenter. Data were recorded in dual circular polarization with a velocity resolution (i.e. channel width) of $\sim$0.1 km s^{-1} and a total velocity coverage of about 55 km s^{-1}. To be able to measure and compare the relative position of the water maser emission across the epochs, we used the phase referencing technique with the close phase calibrator 0333+321 (1.5 degree away). Data were correlated in three separate passes, one per source, at the VLBA correlator in Socorro (New Mexico, USA) with an integration time of 2 seconds. The data reduction was performed using the Astronomical Image Processing System (AIPS) package. The amplitude was calibrated using the template spectra method. The final restoring beam was 1.2×1.2 mas and each channel was cleaned down to a residual rms noise of $\sim$ 15 mJy.

In the first epoch, no emission has been detected towards the four sources. The proto-stars IRAS 4A1+4A2 and IRAS 4B have shown water emission in two of the four epochs observed. This confirms the high variability of the H_2O spots associated with low-mass young stellar objects [9, 2], with an active phase shorter than a few weeks.

Figure 1 reports the July 07th map for IRAS 4B with two groups of H_2O spots mapped: redshited emission at NW $\sim$[+12/+17.0] km s^{-1}, blueshited at SE $\sim$0km s^{-1} (ambient emission is at $V_{\rm LSR}$ = +7.25 km s^{-1}). The size of the water spots chain is about 270 mas ($\sim$60 AU at 235 pc) and its position angle is P.A. $\sim 25^\circ$ NW. As a reference, the dashed circle in Fig. 1 reports the coordinates of IRAS B following [8] who gave the position of the NGC1333 proto-stars, observed at 3.6 cm, with a 50 mas uncertainty (size of the circle). The closest spot to IRAS B, being detected at the level of the uncertainty area, is at $\sim$ 10 AU. The very good alignment of the maser spots as well as their velocities suggest their association with a molecular jet driven by the IRAS B proto-star and having a high degree of collimation (this is consistent with EVN observations of this source by [3]). If we conservatively assume an inclination angle $\simeq 20^\circ$–30°, we derive that the water masers

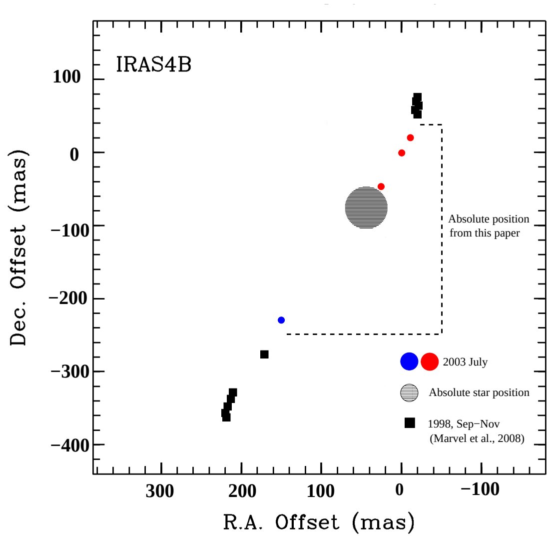

Figure 1: Figure 1. Water maser maps measured for IRAS 4B (July 07th). The map reports the chain of H_2O spots distributed over ∼70 AU. The driving proto-star (hash circle; [8]) is at +66,–95 mas with respect to the center of the present maps, at α_{2000} = 03^h 29^m 12^{s}003, δ_{2000} = +31^o 13′ 08″14. The size of the circle stands for the uncertainty (50 mas) associated with the position of the proto-star. Black square, report the water masers observed by [7], their locations are just indicative with respect to our results.

are moving towards the N-NW (Red) and the S-SE (Blue) direction with velocities $V_{H_2O} \simeq$ 20–150 km s^{-1}, in agreement with the high velocities usually observed along jets form proto-stars.

Our observations are consistent with those recently published by [7] using VLBA observations from 1998 from water masers associated with NGC 1333–IRAS4B. The orientation of the jet traced by the water maser emission has nearly the same position angle (observations of the two projects were separated by five years), and shows high velocities but does not seems to coincide with the large scale outflow located along the N–S direction.

Further observations at high angular resolution of the molecular outflow are needed to clarify whether the disagreement between the molecular outflow and the water jet is due to precession or whether we simply observe different components driven by different sources.

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